


Johnson Space Center Engineering Directorate

L-8: Entry, Descent, and Landing at Mars

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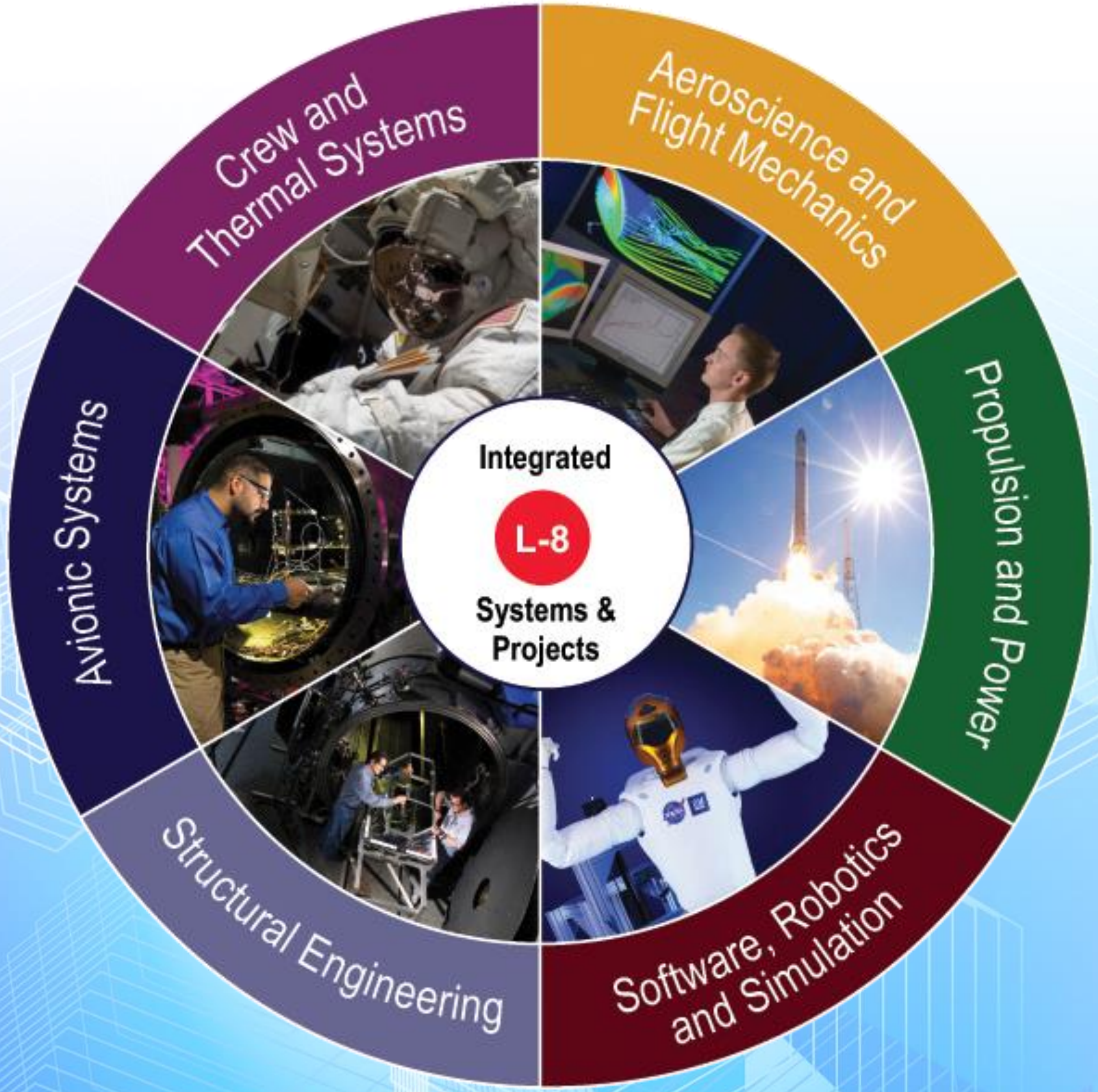
JSC ENGINEERING



JSC Engineering: HSF Exploration Systems Development



- We are sharpening our focus on Human Space Flight (HSF) Exploration Beyond Low Earth Orbit
- We want to ensure that HSF technologies are ready to take Humans to Mars in the 2030s.
  - Various Roadmaps define the needed technologies
  - We are attempting to define our activities and dependencies
- Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025
  - Develop and Mature the technologies and systems needed
  - Develop and Mature the personnel needed
- We need collaborators to make it happen, and we think they can benefit by working with us.

Boilerplate

EA Domain Implementation Plan Overview

JSC Engineering: HSF Exploration Systems Development

- Life Support
- Active Thermal Control
- EVA
- Habitation Systems

- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Deep Space GN&C

- Human System Interfaces
- Wireless & Communication Systems
- Command & Data Handling
- Radiation & EEE Parts

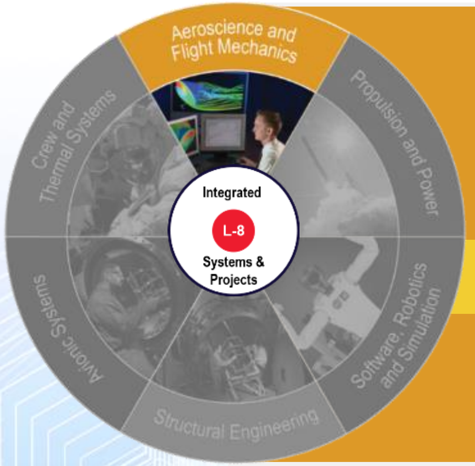
- Reliable Pyrotechnics
- Integrated Propulsion, Power, & ISRU
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Vehicle Environments

- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

AA-2 | iPAS | HESTIA | Morpheus

Aeroscience and Flight Mechanics



- Autonomous Rendezvous & Docking
- Entry, Descent, & Landing
- Deep Space GN&C

The Problem

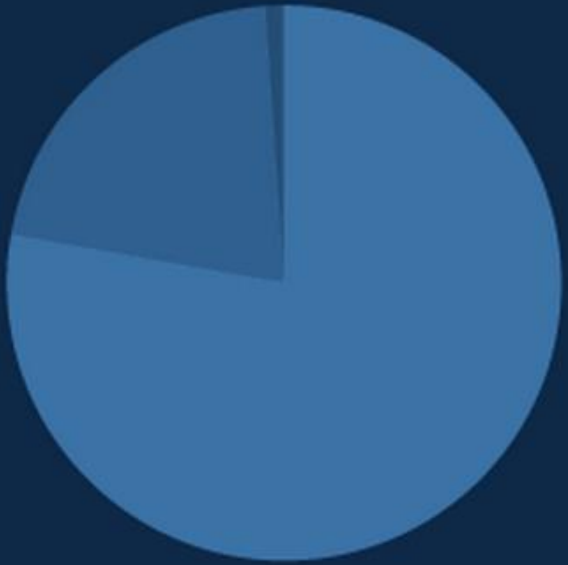
- *Desire to land increasingly large cargo on Mars, and humans in the 2030's*
- *State of the art Mars landed mass is ~1 metric ton (Curiosity rover)*
- *Need to land significantly larger mass payloads to support human missions*
- *Need to land on Mars safely, accurately, and repeatedly for human campaigns*

Entry, Descent, and Landing at Mars

- *Develop a set of technologies to support human planetary landing:*
  - *Slowly*
    - *Entry decelerators*
  - *Accurately*
    - *Terrain Relative Navigation*
  - *Softly*
    - *Altimetry and velocimetry*
  - *Safely*
    - *Hazard Detection and Avoidance*

ATMOSPHERE

[characteristics and approximate composition]



78% NITROGEN

21% OXGYEN

1% OTHER

96% CARBON DIOXIDE

<2% ARGON

<2% NITROGEN

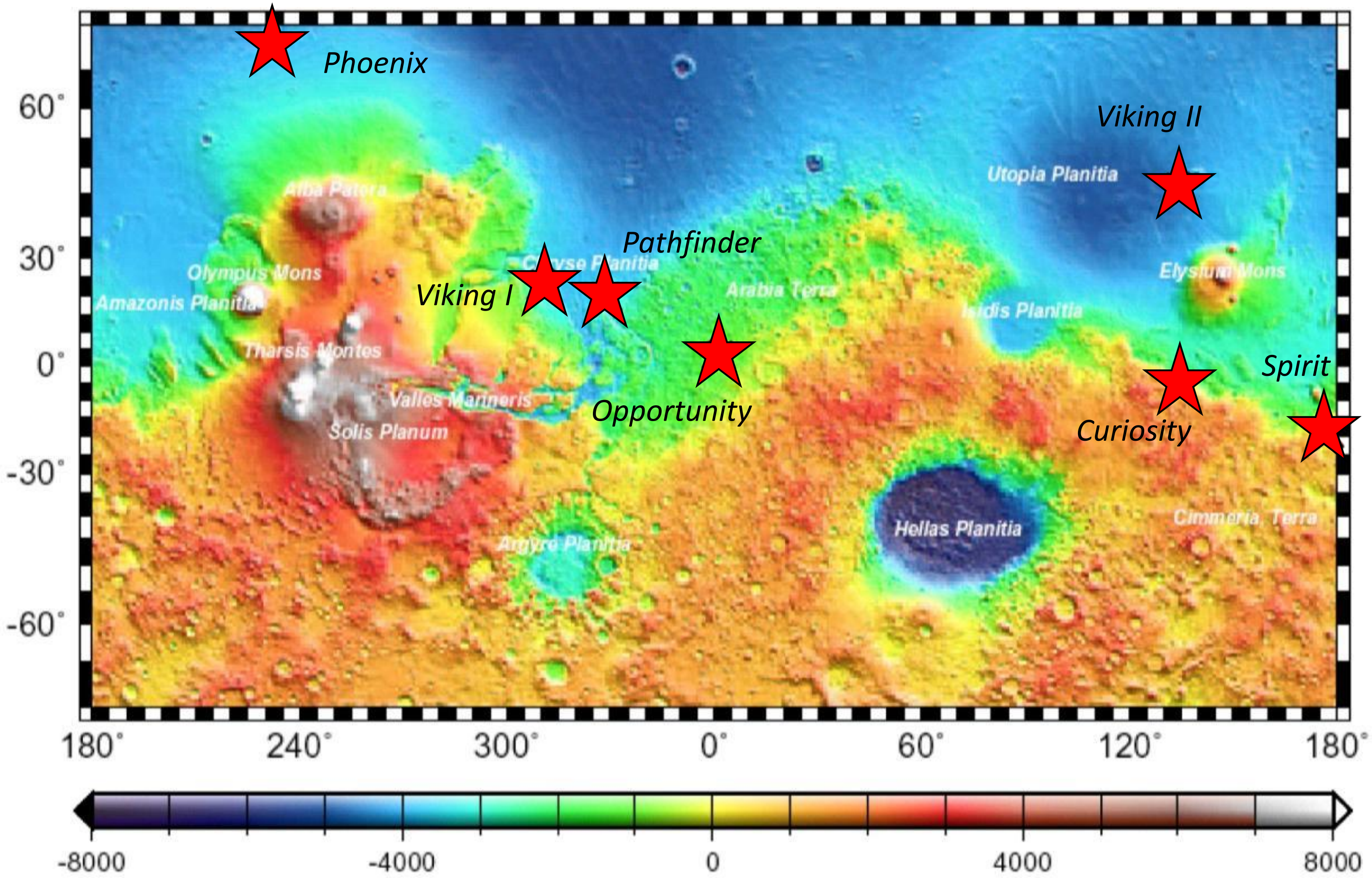
<1% OTHER

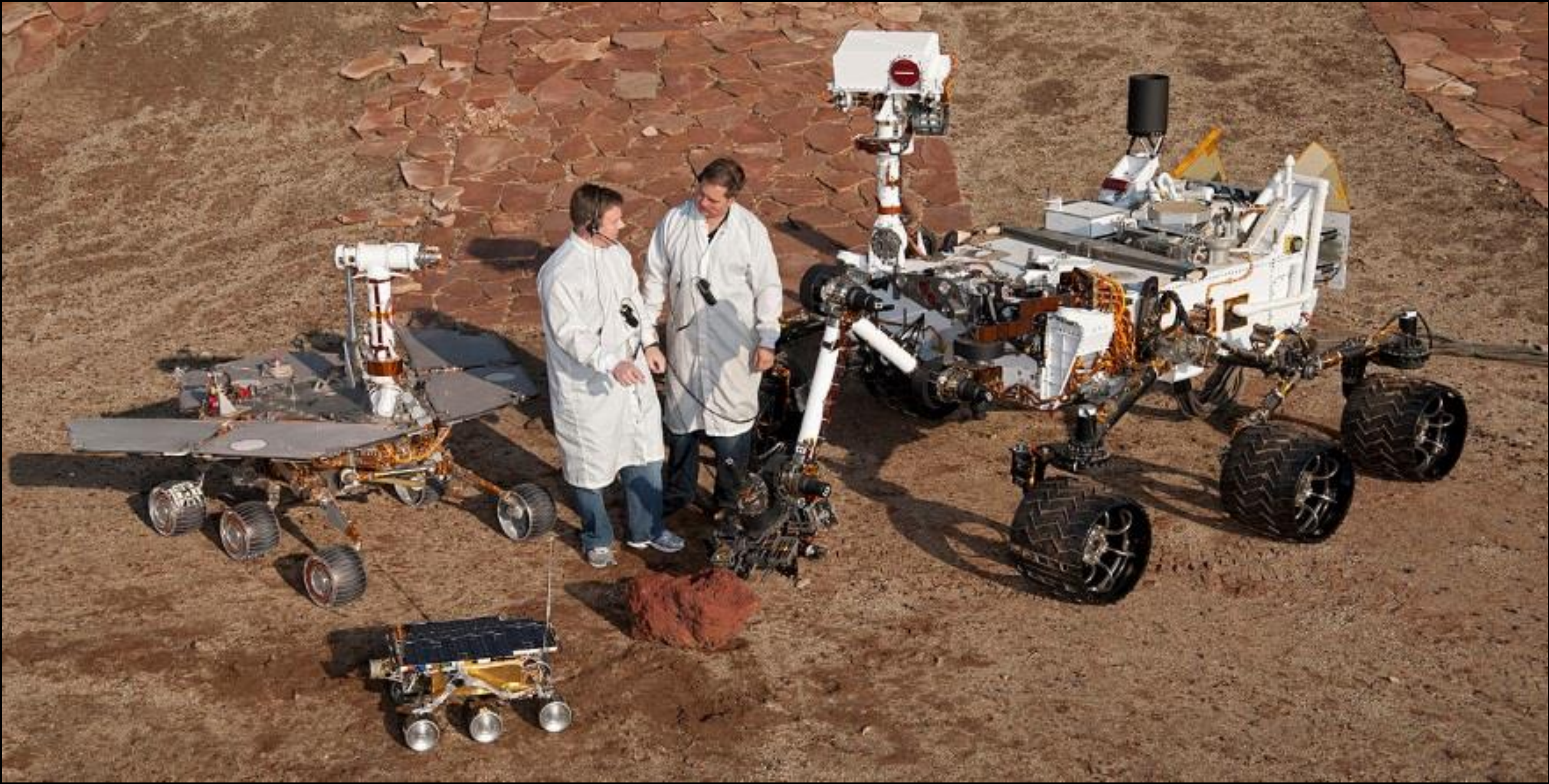
Mach 0.15
“touchdown”

(about 120 mph)

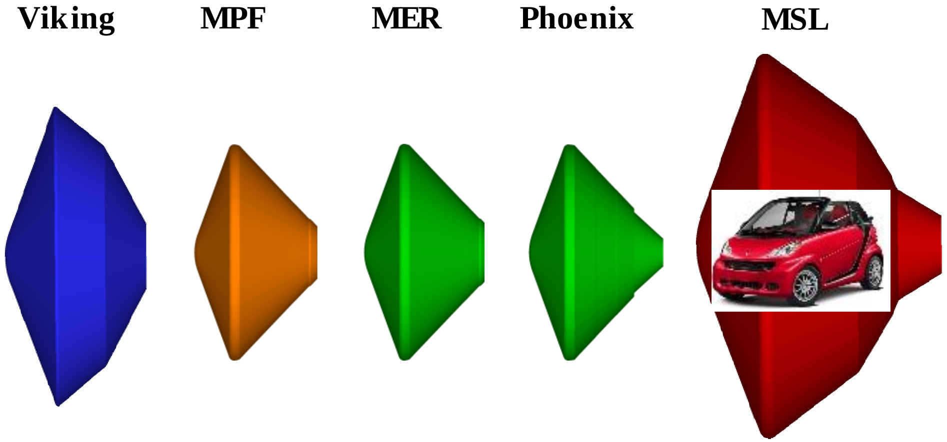
Mach 1.5

7 U.S. Mars Entry, Descent, and Landing Successes





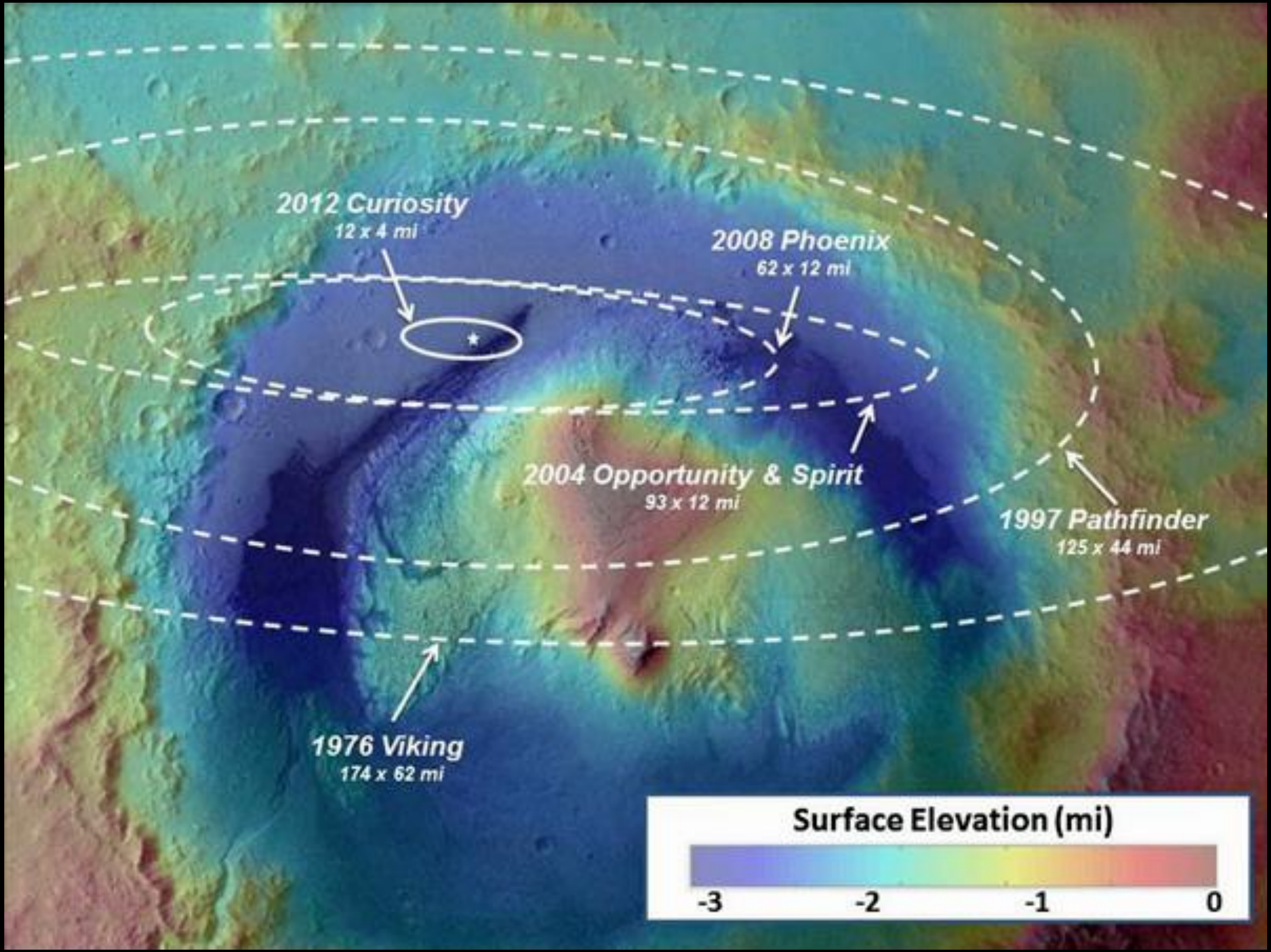
Historical Entry Configurations for Mars Robotic Landings

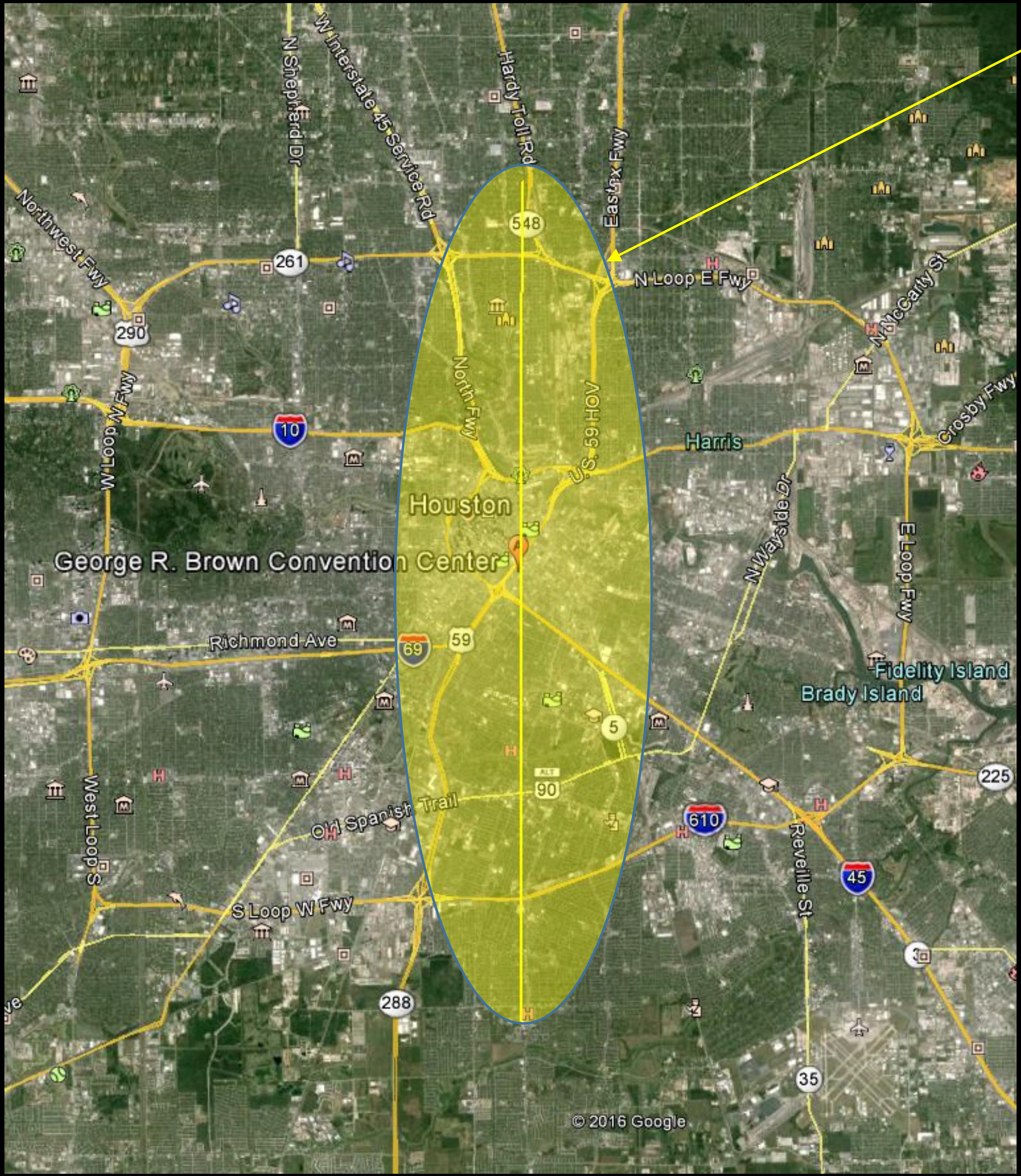


Supersonic
Disk-Gap-Band Parachute

Human Mission Payload Requirement (20 * Curiosity)

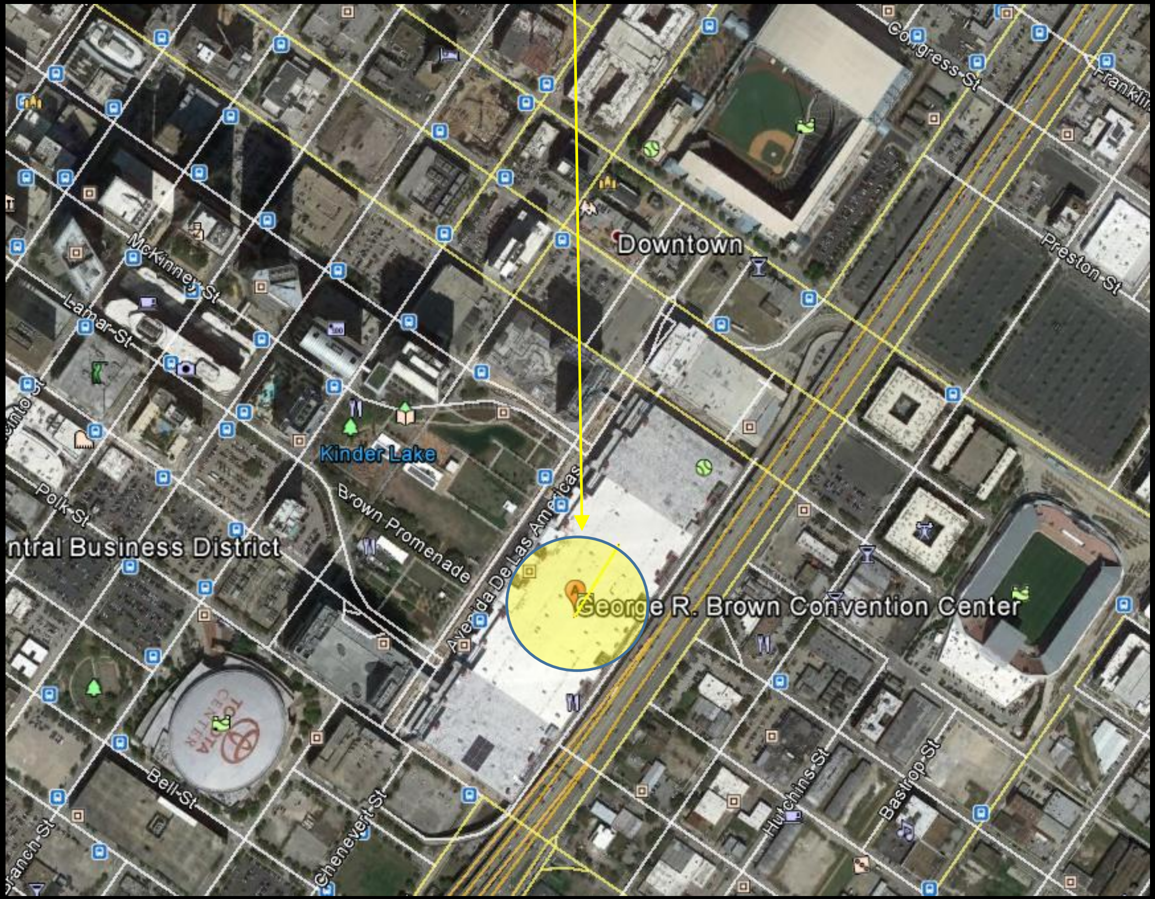
Landing Accuracy





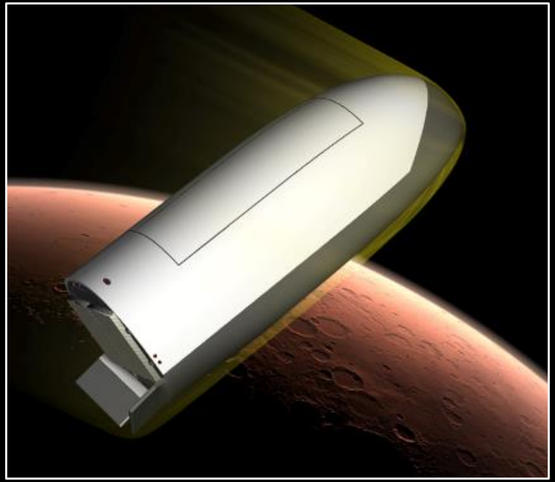
Curiosity
12 x 4 mi ellipse

100 m (or better) accuracy is needed

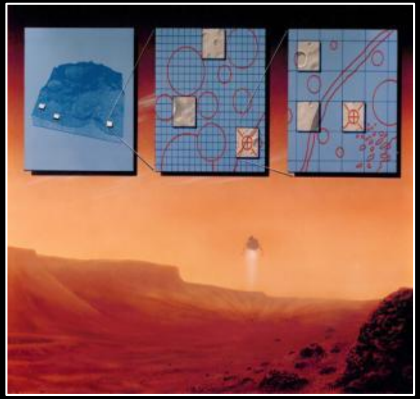


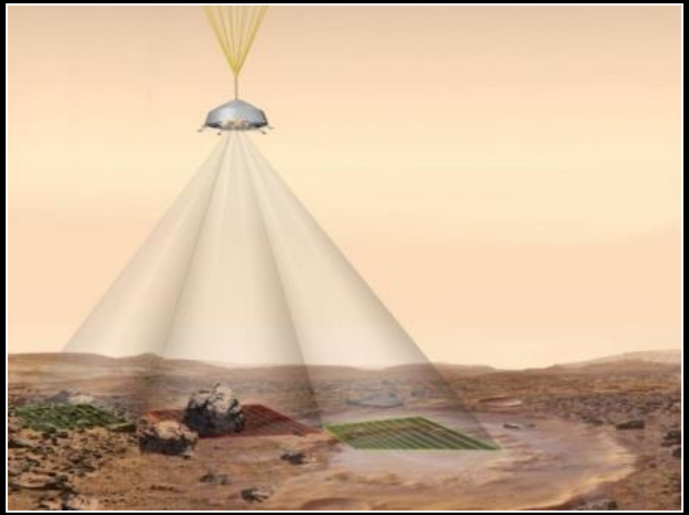
Mars Entry, Descent, and Landing (EDL) Technologies

Entry Decelerators



Precision Landing and Hazard Avoidance



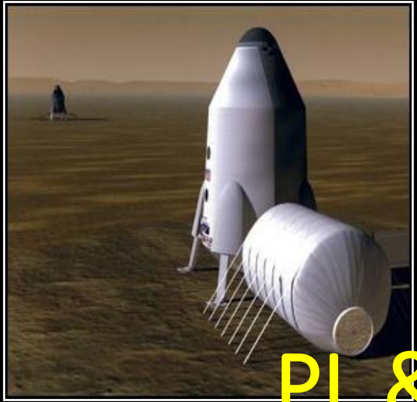


Mars Entry, Descent, and Landing (EDL) Technologies

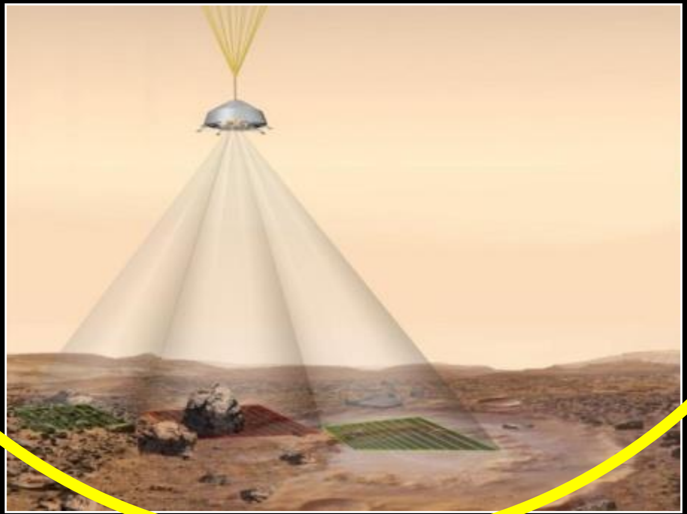
Entry Decelerators

Mid L/D

Precision Landing and Hazard Avoidance



PL & HA



Mid L/D Technology Roadmap and Major Risk Reduction Activities

2016 2017 2018 2019 2020 2021 2022 2028 2030's

Design and Analysis *increasing fidelity* →

Wind Tunnel Testing

Ground Testing (systems)

Potential robotic precursor tech demo (not required for V&V)

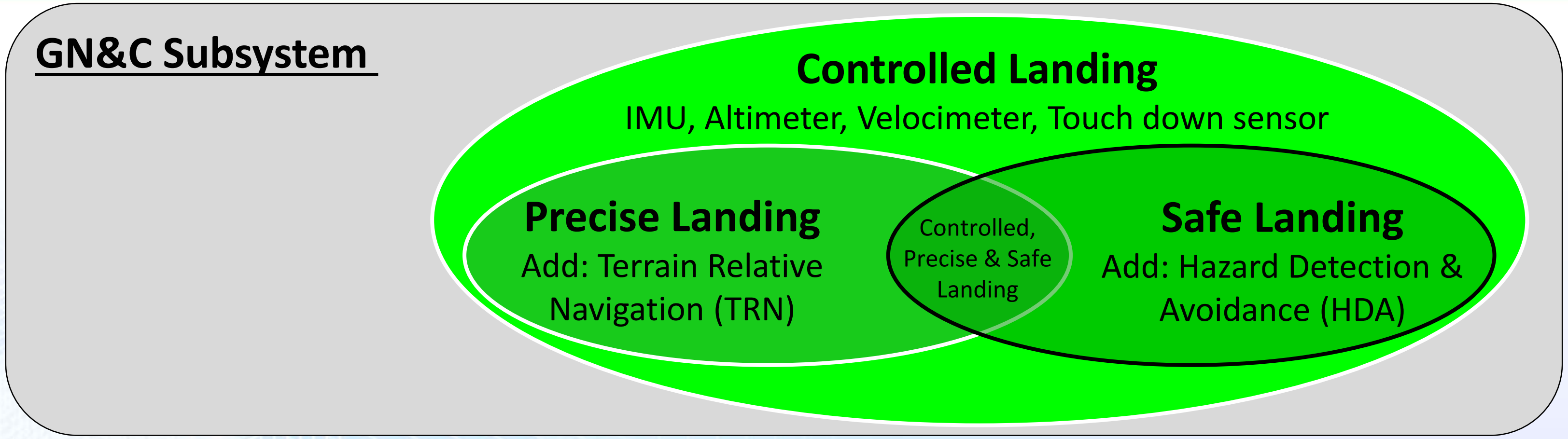
Subscale Earth Demo (full-scale relevant) with integrated supersonic retropropulsion (SRP)

Integrated V&V test for human Mars system for GN&C, aero, aerothermal, SRP, and thermal protection

Small scale EDL from orbit

Additional applications:
- Lunar sample return
- Mars sample return
- Neptune aerocapture
- Missions to other bodies of interest, as applicable

Progression of GN&C Landing System Capabilities
Controlled – Precise – Safe



Controlled Landing
- Minimize vertical descent rate and lateral velocity to ensure a soft (or controlled) touchdown
- No knowledge of global position – "blind" landing

Precise landing – Terrain Relative Navigation (TRN)
- Global navigation through onboard matching of real-time terrain sensing data with *a priori* reconnaissance data
- Enables efficient maneuvering to minimize landing error and avoid large hazards identified in *a priori* analyses

Safe Landing – Hazard Detection & Avoidance (HDA)
- Real-time terrain sensing to identify sites safe from lander-sized hazards that are undetectable in *a priori* data
- Enables a hazard avoidance maneuver to the identified safe site
- Can be leveraged for subsequent Hazard Relative Navigation (HRN) – similar to TRN

Portfolio of PL&HA Technologies

Controlled Landing (Soft Landing)
Velocity & Altitude Sensing

Navigation Doppler Lidar (NDL)
Measures velocity and range

Long-range Laser Altimeter (LAlt)
Measures range

Optical Velocimeter (code)
Estimates velocity with camera images & algorithms

Precise Landing
Terrain Relative Navigation (TRN)

Passive-Optical/Camera-Based
(requires lighted terrain: applicable to most missions)

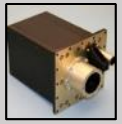
Active/Lidar-based
Can utilize Laser Altimeter or other 3D Lidar. Operates in dark/shadowed or lighted terrain.

GN&C Subsystem
Software

- Navigation techniques for ALHAT
- Guidance logic
- Autonomous Flight Manager

Safe Landing
Hazard Detection (HD) and Hazard Relative Nav (HRN)

Hazard Detection System (HDS)
Lidar used to create hazard map of landing area from multiple images



Compact HDS - Takes single image and finds safe sites

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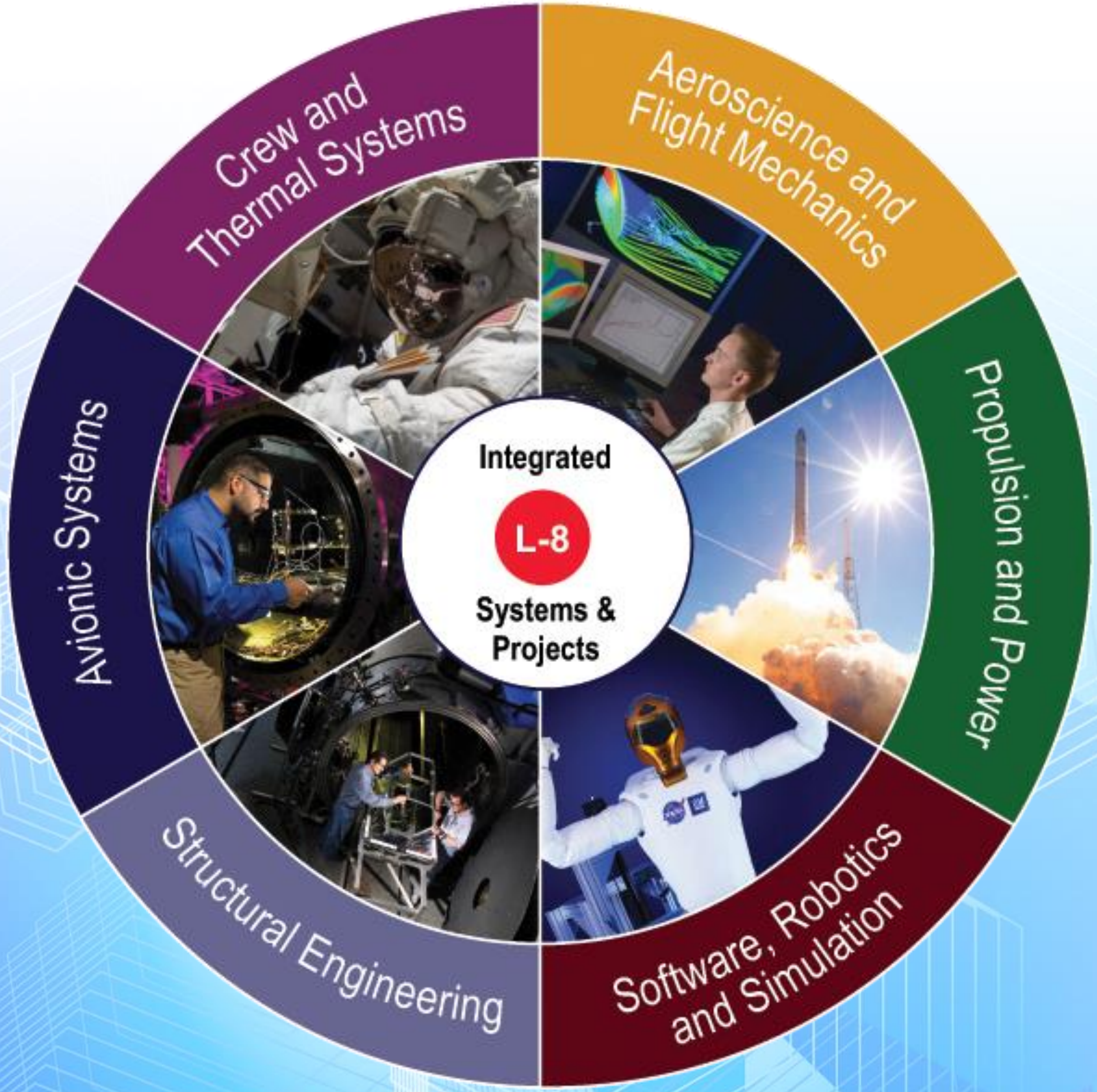

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- Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025
- We need collaborators to make it happen, and we think they can benefit by working with us.
  - Pointer to Co-Dev Announcements
  - Pointer to intake site

Boilerplate

Image from http://www.humanmars.net/2016/01/concept-art-for-martian-movie.html